US009055651B1

(12) **United States Patent**
Radzinski et al.

(10) **Patent No.:** **US 9,055,651 B1**
(45) **Date of Patent:** **Jun. 9, 2015**

(54) **CIRCUIT AND METHOD FOR MONITORING AND REPORTING THE REMAINING USEFUL LIFE OF AN LED MODULE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/031,902**

(22) Filed: **Sep. 19, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/702,860, filed on Sep. 19, 2012.

(51) **Int. Cl.**
H05B 37/04 (2006.01)
H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0893*** (2013.01)

(58) **Field of Classification Search**
USPC 315/129–136, 360
See application file for complete search history.

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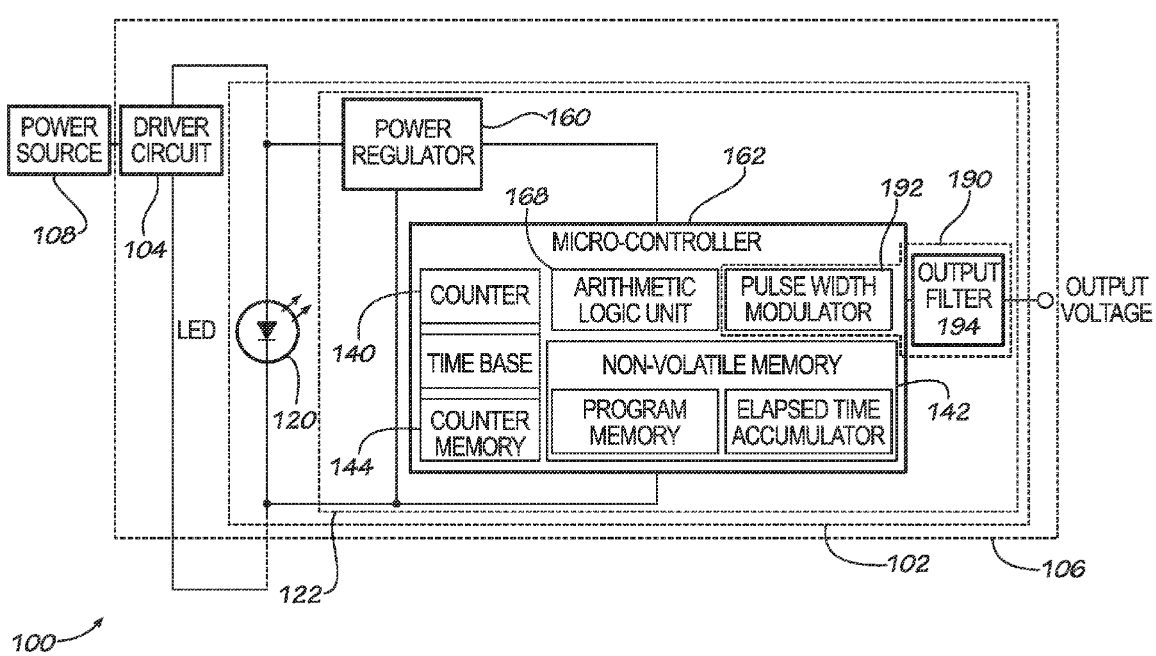
(57) **ABSTRACT**

A light source includes an operating time accumulator (i.e., counter or timer). The light source is operable to be powered by a driver circuit. The light source may be included in a light fixture or independently housed. The light source includes a controller integrally connected with a light emitting diode (LED) of the light source. Whenever the LED is receiving power from the driver circuit, the controller receives power from the driver circuit and accumulates an operating time in a nonvolatile memory of the controller. The nonvolatile memory includes blocks of bits arranged in a hierarchy. All of the bits of any block are in the same level of the hierarchy.

17 Claims, 5 Drawing Sheets



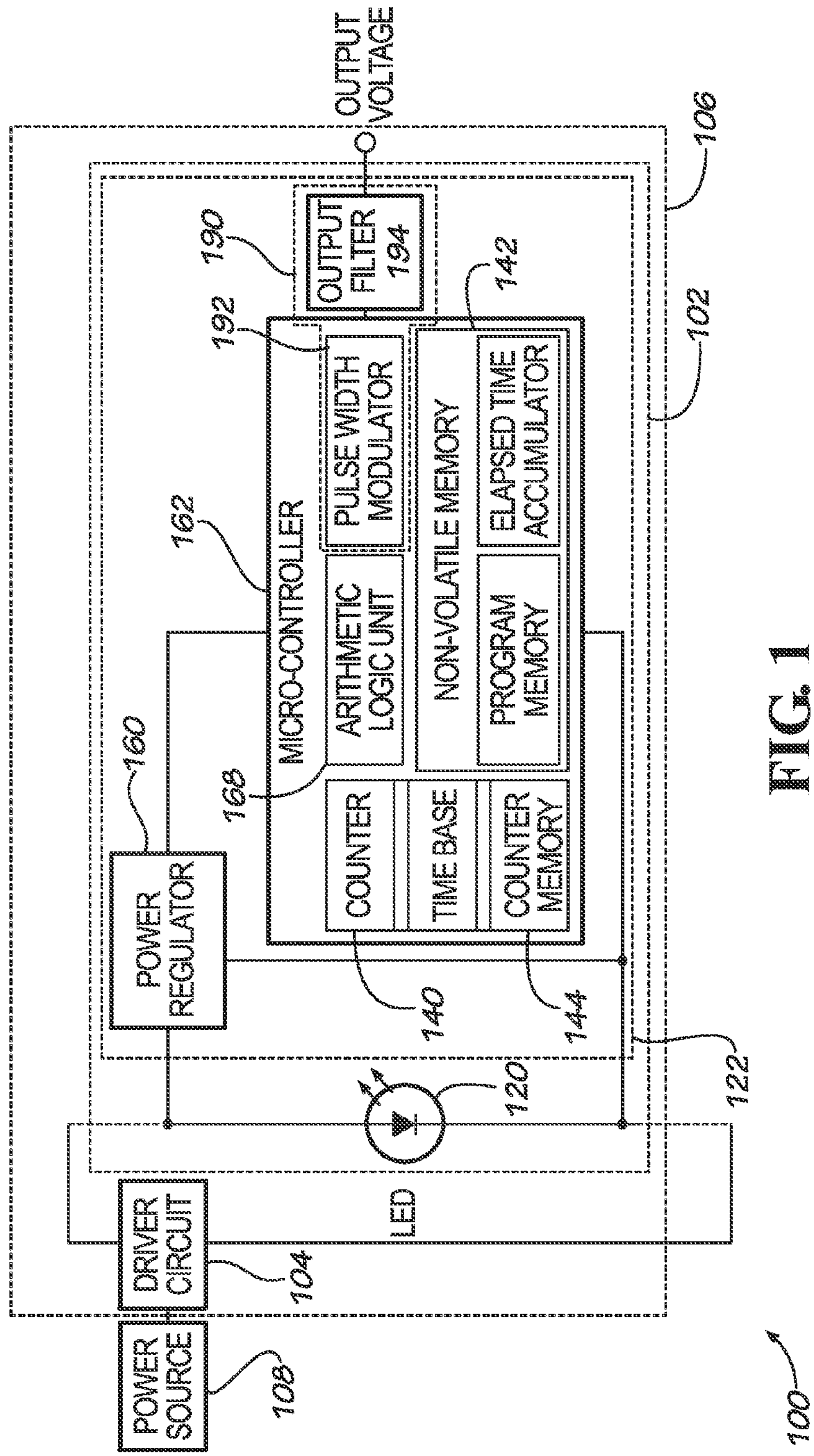

OUTPUT VOLTAGE
106
OUTPUT FILTER 194
190
192
142
102
PULSE WIDTH MODULATOR
NON-VOLATILE MEMORY
ELAPSED TIME ACCUMULATOR
162
MICRO-CONTROLLER
ARITHMETIC LOGIC UNIT
PROGRAM MEMORY
160
168
COUNTER
TIME BASE
COUNTER MEMORY
POWER REGULATOR
140
144
120
122
LED
DRIVER CIRCUIT
104
POWER SOURCE
108
100

FIG. 1

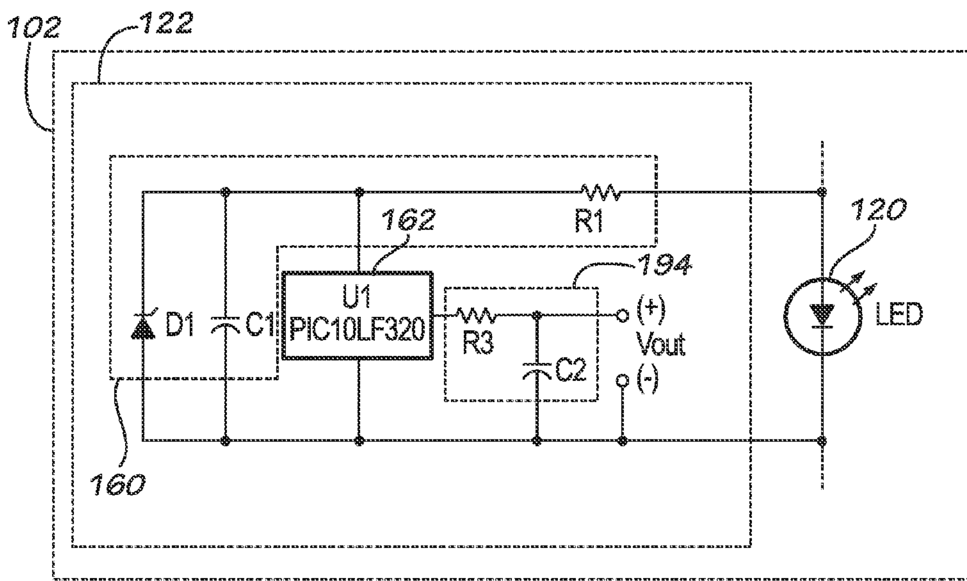


FIG. 2

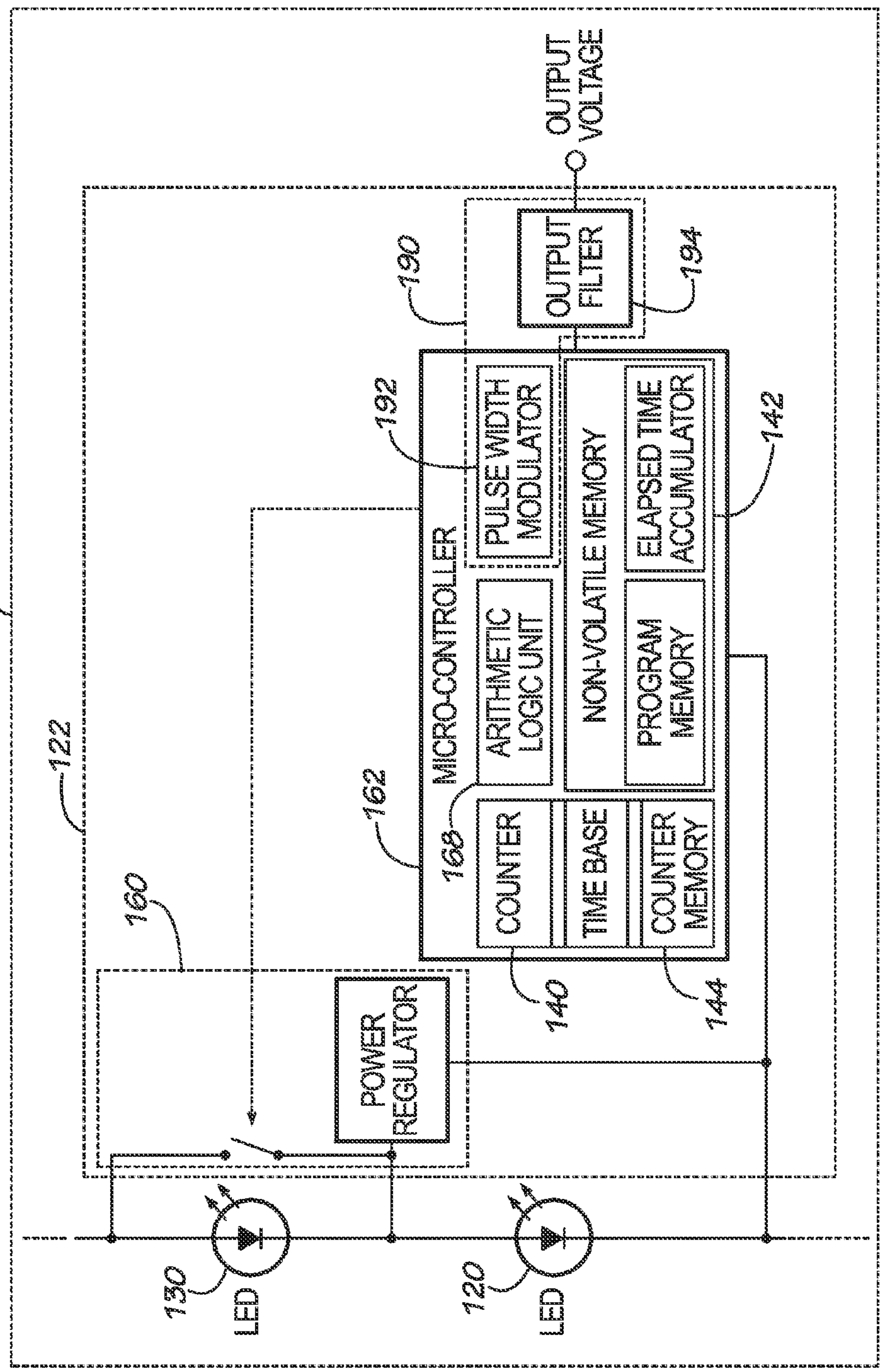

102
122
160
POWER REGULATOR
162
MICRO-CONTROLLER
168
COUNTER
TIME BASE
COUNTER MEMORY
140
144
ARITH-METIC LOGIC UNIT
NON-VOLATILE MEMORY
PROGRAM MEMORY
ELAPSED TIME ACCUMULATOR
142
PULSE WIDTH MODULATOR
192
190
OUTPUT FILTER
194
OUTPUT VOLTAGE
LED
130
LED
120

FIG. 3

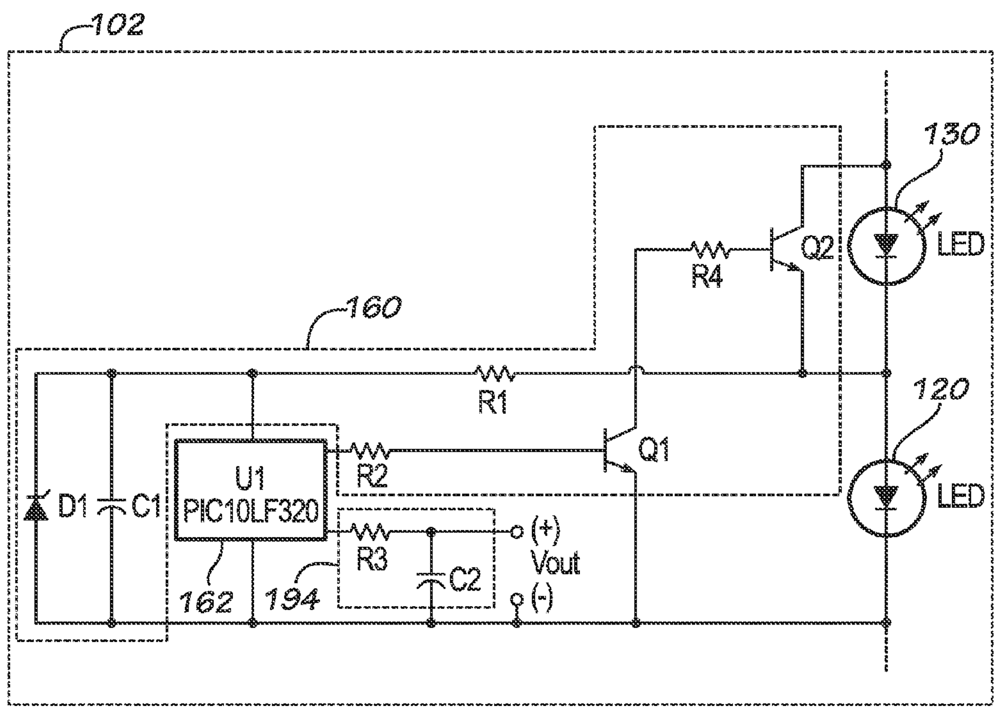

102
130
LED
Q2
R4
160
R1
120
U1
PIC10LF320
R2
Q1
LED
D1
C1
R3
(+)
Vout
C2
(-)
162
194

FIG. 4

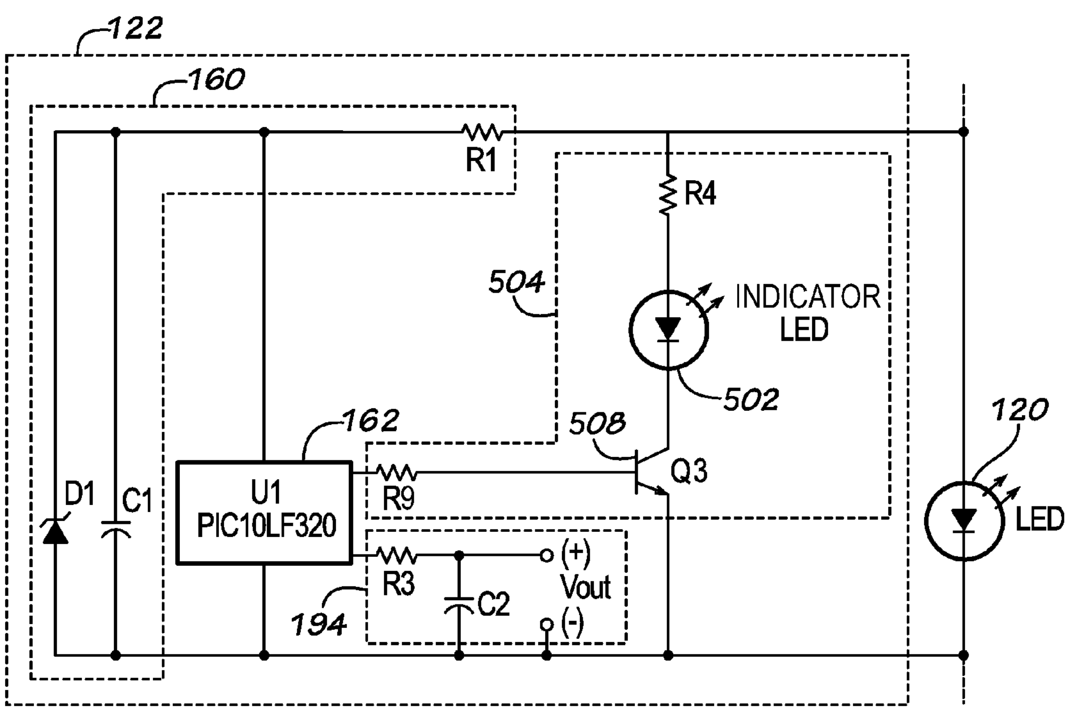

122
160
R1
R4
504
INDICATOR
LED
502
120
162
508
Q3
U1
PIC10LF320
R9
D1
C1
R3
(+)
Vout
C2
194
(-)
LED

FIG. 5

CIRCUIT AND METHOD FOR MONITORING AND REPORTING THE REMAINING USEFUL LIFE OF AN LED MODULE

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims priority to an incorporates by reference herein in its entirety U.S. Provisional Patent Application Ser. No. 61/702,860 entitled "Circuit and Method for Monitoring and Reporting the Remaining Useful Life of an LED Module" filed on Sep. 19, 2012.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO SEQUENCE LISTING OR COMPUTER PROGRAM LISTING APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

The present invention relates generally to methods and circuits to enable identification of failure modes in light sources. More particularly, this invention pertains to circuits and methods for tracking light source usage time to facilitate failure mode recognition.

Light sources have useful lives generally ranging from thousands to millions of hours, depending on the type and configuration of the light source. Knowing an accumulated operating time of a failed light source is useful for warranty evaluation, end-of-life statistics, and failure mode evaluation. Particularly, end-of-life statistics for a light emitting diode based light source is not well known due to their long lifespans and relatively recent widespread use in various applications. Presently, accumulated operating time of a light source is measured only in laboratories, and those measurements are done with rudimentary methods utilizing stopwatches and estimations.

BRIEF SUMMARY OF THE INVENTION

Aspects of the present invention provide a light source including an operating time accumulator (i.e., counter or timer). The light source is powered by a driver circuit. The light source may be included in a light fixture or independently housed. The light source includes a controller integrally connected with a light emitting diode (LED) of the light source. Whenever the LED is receiving power from the driver circuit, the controller receives power from the driver circuit and accumulates an operating time in a nonvolatile memory of the controller. The nonvolatile memory includes blocks of bits arranged in a hierarchy. All of the bits of any block are in the same level of the hierarchy.

In one aspect, a light source includes a light emitting diode (LED) and a controller. The light emitting diode connects to a driver circuit and provides light in response to receiving power from the driver circuit. The controller is connected with the LED and receives power from the driver circuit when the driver circuit is providing power to the LED. The controller includes a counter and a nonvolatile memory. The counter periodically increments a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit. When the count reaches a predetermined limit, the controller restarts the count. The nonvolatile memory stores a representation of a number of times that the count has restarted.

In another aspect, a light fixture includes a light source, a driver circuit, and a housing. The light source includes a light emitting diode (LED) and a controller. The light emitting diode connects to a driver circuit and provides light in response to receiving power from the driver circuit. The controller is connected with the LED and receives power from the driver circuit when the driver circuit is providing power to the LED. The controller includes a counter and a nonvolatile memory. The counter periodically increments a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit. When the count reaches a predetermined limit, the controller restarts the count. The nonvolatile memory stores a representation of a number of times that the count has restarted. The driver circuit connects to the light source and provides power from a power source to the light source. The housing supports the light source and the driver circuit.

In another aspect, a method of determining an operating time of a light source begins with receiving power from a driver circuit at the light source. The light source includes an LED and a controller integrally connected with the LED. The LED provides light in response to receiving power from the driver circuit at the LED. In response to receiving power from the driver circuit at the controller, a counter of the controller periodically increments a count stored in a counter memory of the controller only when the controllers receiving power from the driver circuit. The controller restarts the count when the count reaches a predetermined limit. The controller stores a representation of a number of times the counter has restarted the count in a nonvolatile memory of the controller.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a block diagram of a light fixture including an operating time accumulator.

FIG. **2** is a block and partial schematic diagram of a light source including an operating time accumulator.

FIG. **3** is a block diagram of a light source including an operating time accumulator and a plurality of LEDs.

FIG. **4** is a block and partial schematic diagram of a light source including an operating time accumulator and a plurality of LEDs.

FIG. **5** is a block and partial schematic diagram of a light source including an operating time accumulator and an indicator LED.

Reference will now be made in detail to optional embodiments of the invention, examples of which are illustrated in accompanying drawings. Whenever possible, the same reference numbers are used in the drawing and in the description referring to the same or like parts.

DETAILED DESCRIPTION OF THE INVENTION

While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention.

To facilitate the understanding of the embodiments described herein, a number of terms are defined below. The terms defined herein have meanings as commonly understood by a person of ordinary skill in the areas relevant to the present invention. Terms such as "a," "an," and "the" are not intended to refer to only a singular entity, but rather include the general class of which a specific example may be used for illustration. The terminology herein is used to describe specific embodiments of the invention, but their usage does not delimit the invention, except as set forth in the claims.

As used herein, "ballast" and "driver circuit" refer to any circuit for providing power (e.g., current) from a power source to a light source. Additionally, "light source" refers to one or more light emitting devices such as fluorescent lamps, high intensity discharge lamps, incandescent bulbs, and solid state light-emitting elements such as light emitting diodes (LEDs), organic light emitting diodes (OLEDs), and plasmaloids.

Referring to FIGS. **1-4**, a light fixture **100** includes a light source **102**, a driver circuit **104**, and a housing **106**. The driver circuit **104** connects to the light source **102** and to a power source **108**. The driver circuit **104** receives power from the power source **108** and provides power to the light source **102**. In one embodiment, the power source **108** is an alternating current (AC) line voltage (e.g., 115 V at 60 Hz), and the driver circuit **104** includes an AC to direct current (DC) converter and a buck boost DC-to-DC converter configured as a constant current source. The housing **106** is configured to support the light source **102** and the driver circuit **104**. In one embodiment, the housing **106** further includes a light diffuser, a diffractor, or other lens positioned to distribute or focus light emitted by the light source **102**.

The light source **102** includes a light emitting diode **120** and a controller **122**. The light emitting diode **120** receives power from the driver circuit **104** and provides light in response to receiving the power. As shown in FIGS. **3** and **4**, it is contemplated that the light source **102** may include a plurality of LEDs (e.g., first LED **120** and second LED **130**). The plurality of LEDs may be connected in series, parallel, or a combination thereof.

The controller **122** is integrally connected with the LED **120**. As used herein, integrally connected with the LED **120** means that the controller **122** is electrically connected with the LED **120** such that whenever the LED **120** receives power from the driver circuit **104**, the controller **122** also receives power from the driver circuit **104**. In one embodiment, the controller **122** is configured to receive power only from the driver circuit **104** and to only receive power when the LED **120** is receiving power from the driver circuit **104**.

The controller **122** includes a counter **140** and a nonvolatile memory **142**. The counter **140** periodically increments a count stored in a counter memory **144** of the controller **122**. In one embodiment, the counter memory **144** is a volatile memory integral with the counter. The counter **140** increments a count stored in the counter memory **144** only when the controller **140** is receiving power from the driver circuit **104**. When the count reaches a predetermined limit, the controller **122** restarts the count.

The nonvolatile memory **142** stores a representation of a number of times the counter **140** has restarted the count. In one embodiment, the nonvolatile memory **142** includes a plurality of memory blocks, each block including a plurality of bits. The plurality of memory blocks are arranged in a numerical hierarchy including a plurality of levels. In one embodiment, all of the bits in any block are on the same level of the numerical hierarchy. In one embodiment, the predetermined limit is reached and the counter **140** resets approximately every 16 seconds.

Using a microprocessor **162** such as a PIC10LF320, which has 224 bits per block, a single block can accumulate approximately one hour in this example. Thus, without memory rotation algorithms, a single block can accurately accumulate total elapsed operating time to approximately 100,000 hours. Depending on the amount of nonvolatile memory **142** in the controller **122**, a low cost controller implementing a block level hierarchal memory structure can thus store a representation of a number of times the count has reset that corresponds to millions of hours. In this context, hierarchal means counting in a base other than base 10. For example, with 224 bits per block, any one bit set in a second level block containing 224 bits represents 224 bits in the first level, or approximately 1 hour. Similarly, one bit set in a third level block represents 224 bits in the second level or approximately 50176 total bits. Thus, three hierarchal blocks can represent approximately 50,401 hours in this example.

In one embodiment, the controller **102** further includes a power regulator **160** and a microprocessor **162**. The power regulator **160** is integrally connected with the LED **120**. The power regulator **160** receives power from the driver circuit **104**, regulates the received power to a stable voltage, and provides the stable voltage to the microprocessor **162**. The power regulator **160** may operate at the voltage of a single LED **120**, or may operate at the voltage developed across a plurality of LEDs (see FIGS. **3** and **4**).

The microprocessor **162** includes the counter **140**, the counter memory **144**, the nonvolatile memory **142**, and an arithmetic logic unit **168**. The arithmetic logic unit **168** executes computer executable instructions stored in the nonvolatile memory **142**. The nonvolatile memory **142** stores computer executable instructions for restarting the count by resetting the counter **140** to zero when the count reaches the predetermined limit, and for implementing the representation of the number of times that the counter has been restarted in the nonvolatile memory **142** in response to restarting the counter **140**. It is contemplated that inverse logic may be used with respect to the counter **140** and the representation of the number of times that the counter **140** has been reset stored in the nonvolatile memory **142**. That is, the counter **140** may count up (i.e., increment) from zero to the predetermined limit or count down (i.e., decrement) from another number to a predetermined limit (e.g., zero) within the scope of the claims. It is also contemplated that the nonvolatile memory **142** may be configured to increment from an expected life of the LED **120** down toward zero to accumulate the operational time of the LED **120**.

In one embodiment, the controller **122** further includes an output circuit **190** to provide a signal indicative of the representation of the number of times that the counter **140** has been reset as stored by the nonvolatile memory **142**. The output circuit **190** includes a pulse width modulator **192** and an output filter **194**. The pulse width modulator **192** outputs a pulse width modulated output signal having a duty cycle corresponding to the representation of the number of times that the counter has been restarted. In one embodiment, the pulse width modulator **192** is integral with the microprocessor **162**. In one embodiment, the arithmetic logic unit **160** executes computer executable program instructions stored in the nonvolatile memory **142** to determine the number of times that the counter has been restarted (i.e., reset) based on the accumulated data in the nonvolatile memory **142** and set the duty cycle of the pulse width modulated output signal as a function of the determined number. The output filter **194** smoothes the pulse width modulated output signal to a DC voltage. It is contemplated that the DC voltage may be measured with a handheld voltmeter to determine the accumulated operating time of the LED **120** or light source **102**. Alternatively, additional circuitry may interpret the provided DC voltage to provide a user with a graphical representation of the accumulated (i.e., elapsed) operating time, or remaining operating time of the LED **120** or light source **102**.

Referring to FIG. **5**, in one embodiment, the controller **122** further includes an end of life indicator circuit **504**. The end of life indicator circuit **504** includes an indicator LED **502** and a switch **508**. The indicator LED **502** is operable to provide light in response to receiving power from the driver circuit. In one embodiment, the indicator LED **502** is a narrow band LED or "colored" LED. That is, the indicator LED **502** appears, for example, red, green, or blue when receiving power (i.e., current) and providing light. The switch **508** is connected in series with the indicator LED **502**. The switch **508** is responsive to an enable signal to selectively enable current form the driver circuit to the indicator LED **502**. The controller **122** (e.g., the microprocessor **162**) is operable to provide the enable signal to the switch **508** as a function of the representation of the number of times that the counter **140** has been restarted as stored by the nonvolatile memory **142**. In operation, the controller **122** activates the indicator LED **502** via the switch **508** when the elapsed time or remaining life stored by the nonvolatile memory **142** reaches a predetermined limit such as an end of life time. In one embodiment, there are multiple predetermined limits triggering different actions as the accumulated elapsed time reaches the end of life time. For example, the controller **122** may increase the current provided to the indicator LED **502** (or an array of indicator LEDs **502**) as the stored elapsed time approaches the end of life time. In another example, the controller **122** may flash the indicator LED **502** periodically with an increasing frequency and/or duration as the stored elapsed time approaches the end of life time. In another example, the controller **122** includes multiple indicator LEDs **502** (in one or more packages), each with a different color, and the controller **122** changes which indicator LED **502** is powered and providing light as the stored elapsed time approached the end of life time. For example, the controller **122** may enable power first to a green indicator LED **502**, then to an orange indicator LED **502**, and finally to a red indicator LED **502** when the stored elapsed time has exceeded the end of life time.

It will be understood by those of skill in the art that information and signals may be represented using any of a variety of different technologies and techniques (e.g., data, instructions, commands, information, signals, bits, symbols, and chips may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof). Likewise, the various illustrative logical blocks, modules, circuits, and algorithm steps described herein may be implemented as electronic hardware, computer software, or combinations of both, depending on the application and functionality. Moreover, the various logical blocks, modules, and circuits described herein may be implemented or performed with a general purpose processor (e.g., microprocessor, conventional processor, controller, microcontroller, state machine or combination of computing devices), a digital signal processor ("DSP"), an application specific integrated circuit ("ASIC"), a field programmable gate array ("FPGA") or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. Similarly, steps of a method or process described herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. Although embodiments of the present invention have been described in detail, it will be understood by those skilled in the art that various modifications can be made therein without departing from the spirit and scope of the invention as set forth in the appended claims.

A controller, processor, computing device, client computing device or computer, such as described herein, includes at least one or more processors or processing units and a system memory. The controller may also include at least some form of computer readable media. By way of example and not limitation, computer readable media may include computer storage media and communication media. Computer readable storage media may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology that enables storage of information, such as computer readable instructions, data structures, program modules, or other data. Communication media may embody computer readable instructions, data structures, program modules, or other data in a modulated data signal such as a carrier wave or other transport mechanism and include any information delivery media. Those skilled in the art should be familiar with the modulated data signal, which has one or more of its characteristics set or changed in such a manner as to encode information in the signal. Combinations of any of the above are also included within the scope of computer readable media. As used herein, server is not intended to refer to a single computer or computing device. In implementation, a server will generally include an edge server, a plurality of data servers, a storage database (e.g., a large scale RAID array), and various networking components. It is contemplated that these devices or functions may also be implemented in virtual machines and spread across multiple physical computing devices.

This written description uses examples to disclose the invention and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

It will be understood that the particular embodiments described herein are shown by way of illustration and not as limitations of the invention. The principal features of this invention may be employed in various embodiments without departing from the scope of the invention. Those of ordinary skill in the art will recognize numerous equivalents to the specific procedures described herein. Such equivalents are considered to be within the scope of this invention and are covered by the claims.

All of the compositions and/or methods disclosed and claimed herein may be made and/or executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of the embodiments included herein, it will be apparent to those of ordinary skill in the art that variations may be applied to the compositions and/or methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit, and scope of the invention. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope, and concept of the invention as defined by the appended claims.

Thus, although there have been described particular embodiments of the present invention of a new and useful CIRCUIT AND METHOD FOR MONITORING AND REPORTING THE REMAINING USEFUL LIFE OF AN LED MODULE it is not intended that such references be construed as limitations upon the scope of this invention except as set forth in the following claims.

What is claimed is:

1. A light source comprising:

a light emitting diode (LED) configured to connect to a driver circuit and operable to provide light in response to receiving power from the driver circuit;

a controller integrally connected with the LED and operable to receive power from the driver circuit when the driver circuit is providing power to the LED, said controller comprising

a counter operable to periodically increment a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit, wherein when the count reaches a predetermined limit, the count restarts, and

a nonvolatile memory operable to store a representation of a number of times the controller has restarted the count; and

wherein the counter memory is a volatile memory, and the controller further comprises

a power regulator integrally connected with the LED, wherein the power regulator is operable to receive power from the driver circuit, regulate the received power to a stable voltage, and provide the stable voltage, and

a microprocessor operable to receive the stable voltage from the power regulator, wherein the controller is receiving power from the driver circuit when the microprocessor is receiving the stable voltage from the power regulator, said microprocessor comprising the counter,

the counter memory,

the nonvolatile memory, wherein the nonvolatile memory stores computer executable instructions for restarting the count by resetting the counter to zero when the count reaches the predetermined limit, and incrementing the representation of the number of times that the counter has been restarted in the nonvolatile memory in response to restarting the counter, and

an arithmetic logic unit operable to execute the computer executable instructions stored in the nonvolatile memory.

2. The light source of claim **1**, wherein the nonvolatile memory comprises a plurality of memory blocks, each memory block comprising a plurality of bits, and wherein the plurality of memory blocks are arranged in a numerical hierarchy comprising a plurality of levels.

3. The light source of claim **1**, wherein the nonvolatile memory comprises a plurality of memory blocks, each block comprising a plurality of bits, the plurality of bits in a block of the plurality of memory blocks are all on one level of a numerical hierarchy of the memory blocks.

4. The light source of claim **1**, wherein the controller receives power from the driver circuit only when the driver circuit is providing power to the LED, and the controller is configured to receive power only from the driver circuit.

5. A light source comprising:

a light emitting diode (LED) configured to connect to a driver circuit and operable to provide light in response to receiving power from the driver circuit; and

a controller integrally connected with the LED and operable to receive power from the driver circuit when the driver circuit is providing power to the LED, said controller comprising

a counter operable to periodically increment a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit, wherein when the count reaches a predetermined limit, the count restarts, and

a nonvolatile memory operable to store a representation of a number of times the controller has restarted the count;

an output circuit operable to provide a signal indicative of the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory; and

an end of life indicator circuit comprising:

an indicator LED operable to provide light in response receiving power from the driver circuit;

a switch connected in series with the indicator LED, said switch responsive to an enable signal to selectively enable current from the driver circuit to the indicator LED, wherein the controller is further operable to provide the enable signal to the switch as a function of the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory.

6. A light source comprising:

a light emitting diode (LED) configured to connect to a driver circuit and operable to provide light in response to receiving power from the driver circuit; and

a controller integrally connected with the LED and operable to receive power from the driver circuit when the driver circuit is providing power to the LED, said controller comprising

a counter operable to periodically increment a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit, wherein when the count reaches a predetermined limit, the count restarts, and

a nonvolatile memory operable to store a representation of a number of times the controller has restarted the count;

an output circuit operable to provide a signal indicative of the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory, wherein the output circuit comprises:

a pulse width modulator operable to output a pulse width modulated output signal having a duty cycle corresponding to the representation of the number of times that the counter has been restarted; and

an output filter effective to smooth the pulse width modulated output signal to a direct current (DC) voltage.

7. A light fixture comprising:

a light source comprising

a light emitting diode (LED) operable to receive power and provide light in response to receiving power, and a controller integrally connected with the LED and operable to receive power from the driver circuit when the driver circuit is providing power to the LED, said controller comprising

a counter operable to periodically increment a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit, wherein when the count reaches a predetermined limit, the count restarts, and

a nonvolatile memory operable to store a representation of a number of times the controller has restarted the count;

a driver circuit operable to connect to the light source and provide power from a power source to the light source;

a housing configured to support the light source and the driver circuit; and

wherein the controller further comprises

an output circuit operable to provide a signal indicative of the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory, wherein the output circuit comprises

a pulse width modulator operable to output a pulse width modulated output signal having a duty cycle corresponding to the representation of the number of times that the counter has been restarted; and

an output filter effective to smooth the pulse width modulated output signal to a direct current (DC) voltage.

8. The light fixture of claim **7**, wherein the nonvolatile memory comprises a plurality of memory blocks, each memory block comprising a plurality of bits, and the plurality of memory blocks are arranged in a numerical hierarchy comprising a plurality of levels.

9. The light fixture of claim **7**, wherein the nonvolatile memory comprises a plurality of memory blocks, each memory block comprising a plurality of bits, wherein the plurality of bits in a block of the plurality of memory blocks are all on one level of a numerical hierarchy of the memory blocks.

10. The light fixture of claim **7**, wherein the controller receives power from the driver circuit only when the driver circuit is providing power to the LED, and the controller is configured to receive power only from the driver circuit.

11. The light fixture of claim **7**, wherein the controller further comprises:

an output circuit effective to provide a signal indicative of the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory.

12. A light fixture comprising:

a light source comprising

a light emitting diode (LED) operable to receive power and provide light in response to receiving power, and

a controller integrally connected with the LED and operable to receive power from the driver circuit when the driver circuit is providing power to the LED, said controller comprising

a counter operable to periodically increment a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit, wherein when the count reaches a predetermined limit, the count restarts, and

a nonvolatile memory operable to store a representation of a number of times the controller has restarted the count;

a driver circuit operable to connect to the light source and provide power from a power source to the light source; and

a housing configured to support the light source and the driver circuit;

wherein the counter memory is a volatile memory and the controller further comprises:

a power regulator integrally connected with the LED, wherein the power regulator is operable to receive power from the driver circuit, regulate the received power to a stable voltage, and provide the stable voltage; and

a microprocessor operable to receive the stable voltage from the power regulator, wherein the controller is receiving power from the driver circuit when the microprocessor is receiving the stable voltage from the power regulator, said microprocessor comprising

the counter,

the counter memory,

the nonvolatile memory wherein the nonvolatile memory stores computer executable instructions for restarting the count by resetting the counter to zero when the count reaches the predetermined limit, and incrementing the representation of the number of times that the counter has been restarted in the nonvolatile memory in response to restarting the counter, and

an arithmetic logic unit operable to execute the computer executable instructions stored in the nonvolatile memory.

13. A method of determining an operating time of a light source, said method comprising:

receiving power from a driver circuit at the light source, said light source comprising a light emitting diode (LED) and a controller and integrally connected with the LED;

providing light from the LED in response to receiving power from the driver circuit at the LED;

in response to receiving power from the driver circuit at the controller, periodically incrementing, via a counter of the controller, a count stored in a counter memory of the controller only when the controller is receiving power from the driver circuit;

restarting the count when the count reaches a predetermined limit;

storing a representation of a number of times the controller has restarted the count in a nonvolatile memory of the controller; and

wherein the controller

provides a pulse width modulated output signal, via pulse width modulator of the controller, wherein the pulse width modulated output signal has a duty cycle corresponding to the representation of the number of times that the counter has been restarted as stored by the nonvolatile memory; and

smoothes, via an output filter of the controller, the pulse width modulated output signal to a direct current (DC) voltage.

14. The method of claim **13**, wherein the nonvolatile memory comprises a plurality of memory blocks, each memory block comprising a plurality of bits, and the plurality of memory blocks are arranged in a numerical hierarchy comprising a plurality of levels.

15. The method of claim **13**, wherein the nonvolatile memory comprises a plurality of memory blocks, each memory block comprising a plurality of bits, the plurality of bits in a block of the plurality of memory blocks are all on one level of a numerical hierarchy of the memory blocks.

16. The method of claim **13**, wherein the controller receives power from the driver circuit only when the driver circuit is providing power to the LED, and the controller is configured to receive power only from the driver circuit.

17. The method of claim **13**, further comprising:

providing a signal representative of the number of times that the counter has been restarted as stored by the non-volatile memory via an output circuit of the controller.

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